

FISH ASSEMBLAGE STRUCTURE ACROSS THE ARADE BASIN (SOUTHERN PORTUGAL)

by

Ana M. PIRES (1, 2), Luís Moreira DA COSTA (1),
Maria J. ALVES (1, 3) & Maria M. COELHO (1)

ABSTRACT. - The present work analysed composition and spatial organisation of the fish assemblages across the Arade basin, a small Mediterranean-type catchment in Southern Portugal. This basin is of high conservation priority because it hosts endemic cyprinid species with highly restricted distribution, namely *Squalius aradensis*, an undescribed new species of *Chondrostoma* (u. n. sp. *Chondrostoma*) closely related with *C. lusitanicum*, and *Barbus sclateri*. A total of 12 species were collected in the 39 sites surveyed. Fish assemblages in tributaries were dominated by the Iberian endemic cyprinids, while exotics were dominant in the Arade River. Abiotic variables played an important role in fish assemblage structuring: u. n. sp. *Chondrostoma* was associated to high water temperature and deeper sites, *B. sclateri* preferred sites with high dissolved oxygen, and *S. aradensis* was captured in sites with high current velocity and large dimension substrate. Depth may be particularly important in Mediterranean-type streams, since deeper pools may provide safer refugia against summer drought period. This corresponded to the majority of the Odelouca and Monchique sites and may account for the high abundance and biomass of endemic cyprinids recorded there. The conservation of these two streams, together with Enxerim, should become a priority.

RÉSUMÉ. - Structure de la communauté ichthyologique du fleuve Arade (Sud du Portugal).

Ce travail visait à déterminer la répartition spatio-temporelle des populations ichthyologiques dans le bassin hydrographique de l'Arade, un petit fleuve du sud du Portugal. Ce bassin est considéré prioritaire du point de vue de sa conservation en raison principalement de la présence d'espèces de cyprinidés endémiques dont la distribution est très restreinte, telles que *Squalius aradensis*, une nouvelle espèce non décrite de *Chondrostoma* (*Chondrostoma* n. sp. n. d.) proche de *C. lusitanicum*, et de *Barbus sclateri*. Douze espèces ont été capturées dans 39 stations d'échantillonnage. Le peuplement de poissons dans les différents affluents du fleuve Arade était dominé par les espèces de cyprinidés endémiques, alors que les espèces non-natives/exotiques étaient dominantes dans le fleuve principal. Les facteurs abiotiques jouent un rôle important dans la structuration du peuplement de poissons : *Chondrostoma* n. sp. n. d. était associée aux eaux les plus profondes et avec une température plus élevée, *B. sclateri* préférait les zones avec un taux d'oxygène dissous plus élevé, et *S. aradensis* a été capturé dans les zones présentant un courant plus fort ainsi qu'un substrat plus grossier. La profondeur est un facteur abiotique important, particulièrement dans les rivières du type méditerranéen, quand les mares plus profondes seront des refuges sûrs durant la période sèche estivale. Cela correspond à la majorité des sites des affluents Odelouca et Monchique où l'abondance et la biomasse des cyprinidés endémiques sont plus élevées. Dans un futur proche, la conservation de ces deux rivières, ainsi que l'Enxerim, pourrait devenir une priorité.

Key words. - Cyprinidae - Portugal - Arade River - Mediterranean-type streams - Fish assemblages - Environmental variables - Iberian endemics - Species conservation.

Iberian Peninsula hosts a unique freshwater ichthyofauna with over 80% of the native species endemic to the area (Almaça, 1995; Elvira, 1995; Doadrio, 2001). The geographical isolation from other European catchments by the Pyrenees, together with watershed discreteness and climatic conditions, appear to be the main reasons for this distinctiveness (Almaça, 1976). The widespread distribution of many species of the Cyprinidae family has led to the geographical isolation of many populations. These populations are exposed to a range of environmental constraints, increasing the chances of differentiation (Almaça, 1990).

Southern Iberian catchments with Mediterranean-type

hydrological regime are characterized by extensive seasonal and annual fluctuations (Gasith and Resh, 1999). In these streams, population bottlenecks are common events as a result of summer-early autumn drying, leading to high rates of divergence and production of incipient species (Coelho *et al.*, 1997; Mesquita *et al.*, 2001). Southern Iberian basins are, therefore, of high conservation priority because of the presence of endemic species with highly restricted distribution, in many cases constrained to a single basin or a portion of it (Doadrio *et al.*, 1991; Almaça, 1995; Mesquita and Coelho, 2002). This is particularly the case of the Arade catchment which exhibits three endemic cyprinids. One of which,

(1) Centro de Biologia Ambiental, Departamento de Biologia Animal, Faculdade de Ciências de Lisboa, Campo Grande, Bloco C2-3º Piso, 1749-016 Lisboa, PORTUGAL.

(2) Universidade Atlântica, Antiga Fábrica da Pólvora de Barcarena, 2745-615 Barcarena, PORTUGAL. [apires@uatla.pt]

(3) Museu Nacional de História Natural, Museu Bocage, Rua da Escola Politécnica 58, 1269-102 Lisboa, PORTUGAL.

Squalius aradensis (Coelho, Bogutskaya, Rodrigues and Collares-Pereira, 1998), exhibits a limited spatial range inhabiting only this basin and other small adjacent ones. Other endemic cyprinids present in the Arade basin include *Barbus sclateri* Günther 1868, and an undescribed new species of *Chondrostoma* (u. n. sp. *Chondrostoma*), closely related to *C. lusitanicum* (Collares-Pereira, 1980) (Mesquita *et al.*, 2001; Mesquita and Coelho, 2002). *B. sclateri* has been listed as rare in the Portuguese Red Data Book (SNPRCN, 1991), and similar status has been suggested for both *S. aradensis* and the undescribed *Chondrostoma* due to their limited distributions (Coelho *et al.*, 1995; Mesquita and Coelho, 2002). Despite this interest, little is known about fish assemblage structuring in this small basin (but see Mesquita and Coelho, 2002). Species-environment relationships are fundamental aspects of community ecology and must be on the basis for developing management tools (Copp, 1992). Indeed, earlier studies in Mediterranean-type rivers have presented relevant evidence that microhabitat attributes and local biotic interactions do influence assemblage structure (Godinho *et al.*, 1997a; Godinho and Ferreira, 1998; Martins *et al.*, 1998; Pires *et al.*, 1999). Therefore, the present study addressed the composition and spatial organization of fish assemblages in the Arade basin in relation to environmental variables, in order to define conservation priorities.

MATERIAL AND METHODS

Study area

The Arade basin, with an area of 987 km², flows southwards into the Atlantic Ocean. It is influenced by the typical Mediterranean regime: the climate is temperate, with mean annual temperatures of about 16-18°C and extreme values during summer and winter, and dry (relative humidity < 75%); mean annual precipitation is about 825 mm (moderate raining) with extreme values in "Serra de Monchique" (> 1000 mm) and the semi-arid village of Portimão (between 250-500 mm) (INAG/DRAOTA Algarve, 2000). The Arade catchment shows an irregular annual hydrological regime with droughts and floods. This intermittent regime could induce hydrological stress to fish assemblages, especially during summer and early autumn, when some stretches of rivers are composed by isolated pools.

The rivers of the Arade basin differ in human impact. The Arade River is the most impacted of all, due to the construction of two dams, the Funcho and Arade, which have changed the hydrological regime. Despite being located downstream to both reservoirs, the Enxerim and Falacho streams still exhibit natural habitats; however, due to their reduced dimensions, intermittency may be particularly pronounced herein. The Odelouca, Monchique and Boina tributaries are moder-

ately influenced by human activities, which include wastewater discharges, and gravel extraction in the former. Near-natural deep habitats with heterogeneous riparian cover are still found in both Odelouca and Monchique. The Monchique stream maintains summer flow and presents low water temperature, probably providing refugia for fish when most other rivers dry up. The Boina stream is independent from all the other tributaries, draining directly into the Arade estuary.

Fish fauna of the Arade catchment includes 10 species, eight of which are native (Mesquita and Coelho, 2002). The fish assemblage is dominated by the endemic cyprinid species *S. aradensis*, the u. n. sp. *Chondrostoma* and *B. sclateri*. Other species occurring in this area include the indigenous species *Anguilla anguilla* (Linnaeus, 1758), *Atherina* sp., *Cobitis paludica* De Buen, 1930 (Iberian endemic), *Gasterosteus aculeatus* Linnaeus, 1758, *Chelon labrosus* (Risso, 1826), and the exotic species *Lepomis gibbosus* (Linnaeus, 1758) and *Gambusia holbrooki* Girard, 1859.

Sampling

A total of 39 sites on seven streams of the Arade basin were selected for this study, i.e., Arade (six sites), Enxerim (three sites), Falacho (two sites), Odelouca (eighteen sites), Monchique (seven sites) and Boina (three sites) (Fig. 1). The different number of sites sampled in each river could be considered as representatives of the different types of habitats presented in those rivers. Sampling was undertaken continuously from the end of April to the middle of May 1997.

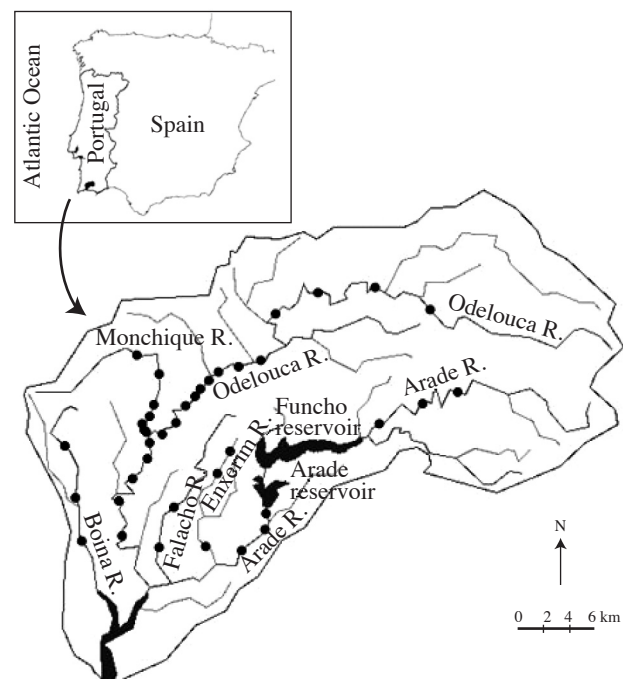


Figure 1. - Map of the Arade basin, showing sampled rivers. [Carte du bassin de l'Arade, montrant les rivières échantillonnées.]

	Abundance (nb fish per 50 m)			Biomass (g per 50 m)	
	% Occ.	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range
<i>Squalius aradensis</i>	39.7	28.4 $\pm$ 30.9	0-105	166.3 $\pm$ 208.1	0-833.2
u. n. sp. <i>Chondrostoma</i>	27.6	19.8 $\pm$ 38.1	0-161	86.6 $\pm$ 169.8	0-818.8
<i>Barbus sclateri</i>	2.5	1.8 $\pm$ 5.4	0-27	34.9 $\pm$ 170.5	0-1059.7
<i>Anguilla anguilla</i>	13.3	9.5 $\pm$ 9.3	0-33	206.9 $\pm$ 237.7	0-1233.1
<i>Cobitis paludica</i>	12.7	9.1 $\pm$ 8.4	0-31	24.5 $\pm$ 24.5	0-78.7
<i>Atherina</i> sp.	1.2	0.9 $\pm$ 3.4	0-21	1.7 $\pm$ 5.7	0-33.8
Mugilidae sp.	0.4	0.3 $\pm$ 1.1	0-6	21.2 $\pm$ 90.1	0-477.5
Exotic species	2.5	1.8 $\pm$ 6.5	0-39	24.0 $\pm$ 93.0	0-535.7

Table I. - Fish assemblages in the Arade basin quantified using percentage occurrence of individuals (% Occ.) and the mean ($\pm$ SD) and range of the abundance and biomass for the species sampled. Exotics species are: *Cyprinus carpio*, *Micropterus salmoides*, *Herichthys facetum*, *Lepomis gibbosus* and *Gambusia holbrooki*. [Peuplement de poissons dans le bassin de l'Arade quantifié par le % d'occurrence des individus (% Occ.) et la moyenne ($\pm$ SD) et l'amplitude de l'abondance et de la biomasse des espèces échantillonnées.]

Fishes were sampled by electric fishing (DC at 300/600 V and 4-6 A) during 20 minutes on an approximately 50 m stretch of stream, wading in upstream direction. All fishes captured were identified, measured for fork length (FL to the nearest mm), weighted (nearest 0.1 g) and returned alive at their point of capture. Catch-per-unit-effort (CPUE) (min^{-1}) was used to index fish abundance at each site. A set of ten environmental variables was recorded at each site. Five transects were defined along each stream reach and measurements were taken for water depth (cm), current velocity (m/s), temperature ($^{\circ}\text{C}$), dissolved oxygen (mg/l), pH, conductivity (mS), dominant substratum type ([1] organic cover; [2] silty sand (1-2 mm); [3] sand (2-5 mm); [4] gravel (5-25 mm); [5] small pebbles (25-50 mm); [6] large pebbles (50-100 mm); [7] cobble (100-250 mm); [8] boulder (> 250 mm)), slope (%), river width (m), river length (m) and cover (%) (aquatic and riparian vegetation). Sampling protocol for environmental variables followed Gorman and Karr (1978).

Data analysis

Analysis focused in describing the variation in species abundance, biomass and size-distribution among tributaries. In the species abundance and biomass matrices, the endemic cyprinids were individually considered while the remaining native and exotic species were grouped in the categories 'others' and 'exotics', respectively. For the Arade River another analyses was performed considering upper and lower dams sites. The size-distribution of each endemic cyprinid was determined according to the total range of sizes caught. The species richness was used to assess cyprinid importance (Ludwig and Reynolds, 1988).

The abundance and environmental data matrices, with separated sites by each tributary, were submitted to canonical correspondence analysis (CCA) (ter Braak, 1987-1992), a direct gradient ordination technique, to relate CPUE of individual fish species in the multivariate space described by environmental factors (5 'species' $\times$ 8 environmental variables $\times$ 39 sites). CCA is a powerful exploratory tool for simplifying complex data sets and has the advantage over meth-

ods of indirect gradient analysis of allowing integrated analysis of both species and environmental data at each site (Taylor *et al.*, 1993; ter Braak and Verdonschot, 1995; Matthews, 1998). The abundances of species can be examined with respect to similarities and differences among species, and with respect to the ways the fishes are related to environmental variables (Matthews, 1998). The CCA was obtained with CANOCO v.4.0 program (ter Braak, 1987-1992; ter Braak and Smilauer, 1998). The resulting species-environmental biplot is an ordination diagram in which species and sites are represented by points with respect to the supplied explanatory variables, represented by arrows. The arrows point in the direction of maximum variation in value of the corresponding variable (ter Braak, 1986). Although all environmental variables were initially included for the CCA analysis, those with high variance inflation factors (indicating strong multicollinearity) were removed (such as slope and river length). Statistical significance in CCA was determined using Monte Carlo permutation tests (with 999 permutations) on both the first axis eigenvalue and the trace statistics (ter Braak, 1987-1992).

RESULTS

A total of 2,789 fishes belonging to seven native and five exotic species were collected over all sites (Tab. I). *Squalius aradensis* were the most numerous fish (39.7%), occurring in 87.2% of the samples. The frequency of occurrence was also high for *Anguilla anguilla* (84.6%) and *Cobitis paludica* (82.1%), but they were captured in low numbers (13.3% and 12.7%, respectively). The undescribed *Chondrostoma* was the second most numerous species accounting for 27.6% of the catches, but was less frequent occurring at 69.2% of the sites. *Barbus sclateri* represented only 2.5% of the overall catches and was restricted to the Odelouca and Monchique tributaries, where they only occurred at a few sites (25.6%). Exotic species, including *Cyprinus carpio* Linnaeus, 1758, *Micropterus salmoides* (Lacépède, 1802),

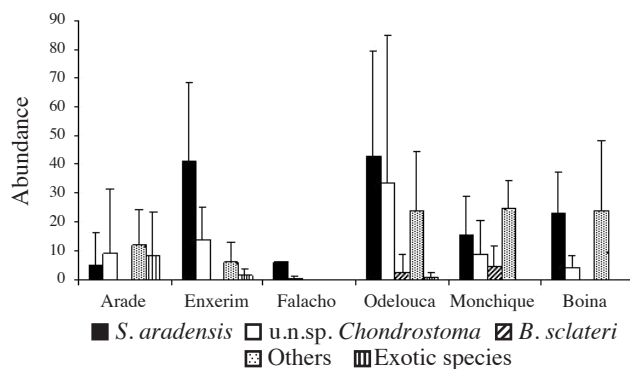


Figure 2. - Mean ($\pm$ SD) of abundance (number of fish per 50 m) for the sampled rivers of the Arade basin. [Moyenne ($\pm$ SD) de l'abondance (nombre de poisson par 50 m) pour les rivières échantillonnées dans le bassin de l'Arade.]

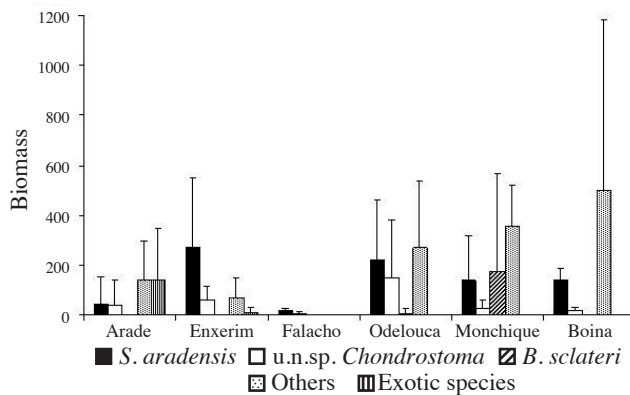


Figure 3. - Mean ($\pm$ SD) of biomass (g per 50 m) for the sampled rivers of the Arade basin. [Moyenne ($\pm$ SD) de la biomasse (g par 50 m) pour les rivières échantillonnées du bassin de l'Arade.]

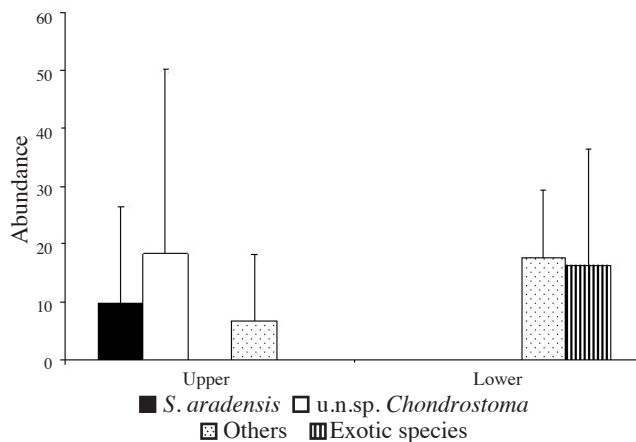


Figure 4. - Mean ($\pm$ SD) of abundance (number of fish per 50 m) for the upper and lower sampled sites at the Arade River. [Moyenne ($\pm$ SD) de l'abondance (nombre de poisson par 50 m) pour les sites échantillonnés en amont et en aval de la rivière Arade.]

Herichthys facetum (Jenyns, 1842), *Lepomis gibbosus* (Linnaeus, 1758) and *Gambusia holbrooki* Girard, 1859, were also captured in low numbers and occurred in few sites

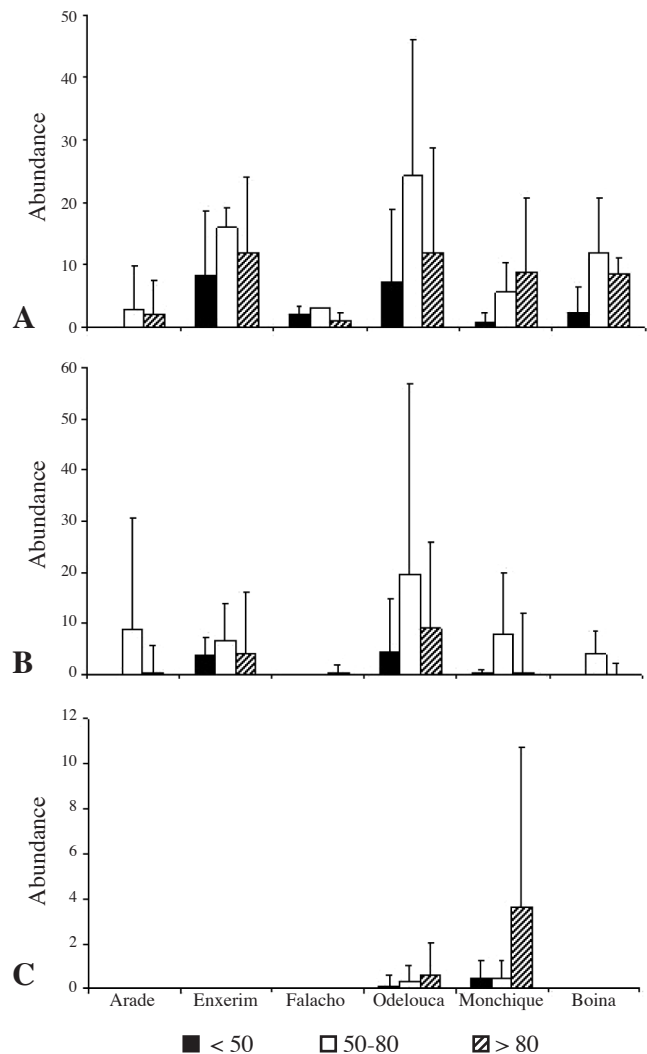


Figure 5. - Abundance (number of fish per 50 m) by size-classes for each endemic cyprinids analysed separately in the sampled rivers of the Arade basin. A: *S. aradensis*; B: u.n.sp. *Chondrostoma*; C: *B. sclateri*. [Abondance (nombre de poissons par 50 m) par taille de classes pour chaque espèce de cyprinidés endémiques, analysée séparément dans les rivières échantillonnées du bassin de l'Arade.]

(2.5% and 23.1%, respectively).

At the majority of tributaries, fish assemblages were dominated by the Iberian endemic cyprinids, both in terms of abundance (Fig. 2) and biomass (Fig. 3). *S. aradensis* and u.n.sp. *Chondrostoma* were the dominant species among most rivers sampled, although their abundance and biomass varied significantly. The highest abundance values for these species were observed in Odelouca, but the highest biomass for *S. aradensis* was recorded in Enxerim. Although generally scarce, *B. sclateri* was the second most important species in biomass in Monchique. The Arade River was an exception to this pattern, as fish assemblages were generally very poor, without endemic cyprinids downstream the dams (Fig. 4). Exotic species, in particular *M. salmoides*, showed

considerable importance in the fish assemblage, dominating both in abundance and biomass at a few sites. The group 'others' accounted significantly for biomass in Odelouca, Monchique and Boina (Fig. 3), in particular in the latter, *A. anguilla* being the most abundant species in this group. Monchique and Odelouca showed the highest values of mean total biomass (694.1 g and 653.5 g, respectively), and Falacho the lowest (24.2 g).

Endemic cyprinid species richness varied among tributaries, indicating that Odelouca and Monchique are different from all other tributaries sampled, showing the highest endemic cyprinid richness.

Length-distribution for the three endemic cyprinids varied among tributaries. Only the Odelouca and Monchique rivers showed all the size-classes for the three species. Each *S. aradensis* size-class was represented at all tributaries with the exception of the Arade, where fish smaller than 50 mm were not caught (Fig. 5A). All size-classes of u.n.sp. *Chondrostoma* were only present at Enxerim, Odelouca and Monchique, being Odelouca the stream where all size-classes were more represented (Fig. 5B). All size-classes of *B. sclateri* were also observed in Odelouca and Monchique (Fig. 5C). Nevertheless, *B. sclateri* larger than 80 mm were particularly abundant in Monchique, probably accounting for the high biomass recorded there (Fig. 5C).

The first two axes in the CCA accounted for 24.7% of variance in the fish abundance matrix. Although trace statistics were only nearly statistically significant ($P = 0.11$; n.s. for the trace: Monte Carlo simulation test with 999 permutations), the pattern in species-environment biplot was still ecologically relevant (Fig. 6A, B). Indeed, the biplot generated by the CCA (Fig. 6A) suggested that depth was the most important variable for the first axis, together with current velocity (Tab. II). For the second axis, conductivity was a very important variable, although depth and oxygen were still influential. Canonical coefficients for these variables were significantly correlated ($p < 0.05$) with axis 1 and axis 2. High water temperature and deep sites were associated with u.n.sp. *Chondrostoma*, and were particularly related to Odelouca. *B. sclateri* preferred sites with high dissolved oxygen and the presence of cover, which correspond to the Monchique sites. *S. aradensis* and 'other' species were associated with high current velocity and substrate of large dimension, which correspond to Odelouca sites. The exotic species clearly associated with high conductivity such it occurred in the Arade tributary. Another CCA performed with size-classes groups (11 'species' x 8 environmental variables x 39 sites) instead of CPUE yielded similar results and was not presented here.

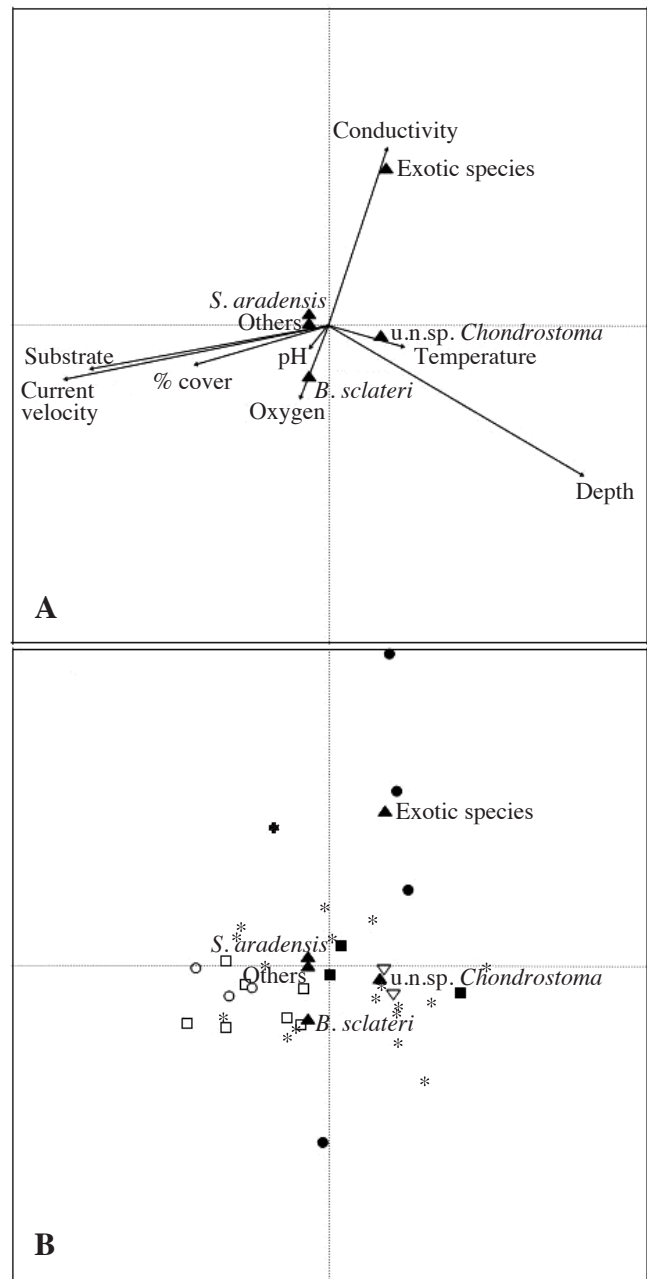


Figure 6. - Ordination diagram based on a canonical correspondence analysis. **A:** Fish taxa and environmental variables assessed in 39 sites of the Arade basin. Species scores are labelled and arrows represent environmental variables. The length of the arrow is relative to the importance of that explanatory variable in assemblage ordination; **B:** Sites scores, labelled with respective tributaries (Arade ●, Enxerim ■, Falacho ▽, Odelouca *, Monchique □ and Boina ○). [Diagramme d'ordination basé sur une analyse canonique des correspondances. **A:** Taxons de poissons et variables environnementales évaluées dans 39 sites du bassin de l'Arade. Les résultats sont indiqués par espèces, et les flèches représentent les variables environnementales; **B:** Résultats par site, en fonction des affluents (Arade ●, Enxerim ■, Falacho ▽, Odelouca *, Monchique □ et Boina ○).

Table II. - Canonical coefficients and the intraset correlations of environmental variables with the first two axes of canonical correspondence analysis for the 39 sites. Eigenvalues were 0.19 for the first axis and 0.12 for the second axis. *: significant $p < 0.05$. [Coefficients canoniques et corrélations des variables environnementales avec les deux premiers axes de l'analyse canonique des correspondances pour les 39 sites. Les valeurs propres étaient de 0,19 pour le premier axe et de 0,12 pour le second. *: p significatif $< 0,05$.]

Axis variable	Canonical coefficients		Correlation coefficients	
	1	2	1	2
Depth	0.54 *	-	0.61	-0.25
Current velocity	-0.34	-0.27	-0.64	-0.09
Temperature	0.19	-0.28	0.19	-0.04
Conductivity	0.11	0.51 *	0.14	0.29
pH	0.35	0.85	-0.04	-0.03
Oxygen	-0.50	-	-0.07	-0.13
Cover	-0.24	-0.38	-0.33	-0.07
Substrate	-0.11	-0.23	-0.58	-0.07

DISCUSSION

The Arade catchment, as other small southern Iberian basins, has a depauperate and highly endemic fish fauna of high conservation importance. When compared with the neighbour basins, this fish assemblage presents lower values for both abundance and biomass as well as species richness than that of Guadiana, one of the largest and richest Iberian basins (Godinho *et al.*, 1997a; Pires *et al.*, 1999), but was similar to that of the Mira (Magalhães *et al.*, 2002b), a smaller neighbour basin.

From all the species previously described for the Arade basin (Mesquita and Coelho, 2002), only *Gasterosteus aculeatus* was not found in the present study. Although *Chondrostoma polylepis* Steindachner has been recorded in the Funcho and Arade dams (Coelho *et al.*, unpubl. data), it was not found in the tributaries sampled. This species was probably introduced from the Tejo or Sado basins, given it is absent in the Guadiana (Godinho *et al.*, 1997a; Pires *et al.*, 1999). On the other hand, some species presently collected have not been sampled in previous studies, namely *Cyprinus carpio*, *Micropterus salmoides* and *Herichthys facetum*.

The fish abundance, species richness and biomass reached the highest values in Odelouca and Monchique corresponding to sites with less human activities. *Squalius aradensis* and u.n.sp. *Chondrostoma* were present in all rivers, but *Barbus sclateri* was only caught in these two tributaries. As previously found by Mesquita and Coelho (2002), exotics species were in general rare, with no relevance for the fish assemblage. However, they were dominant in the Arade River. The construction of the Funcho and Arade dams changed the hydrologic regime from lotic to lentic,

modifying some abiotic and biotic factors (Angermeier, 1985; Cowx and Welcomme, 1998), which may have favoured the adaptation of introduced piscivorous species and increased their impact on the native fish assemblages (Matthews, 1998). Nevertheless, the low fish density and the absence of *B. sclateri* in the Arade River may also be the result of poor electric fishing sampling efficiency in larger deeper habitats (Harvey and Cowx, 1996). Some disastrous effects of large river regulation upon species richness have been recorded, and negative effects of both channelization and damming upon native fish may result in both isolation and fragmentation of the populations (Sheldon, 1988). In streams highly disturbed by channelization, relative importance of introduced species is usually increased, leading to low native fish species richness (Schlosser, 1991). In the Guadiana basin, the decline or even the disappearance of the endemic fish populations is likely related to the presence of exotic species (Godinho *et al.*, 1997b; Collares-Pereira *et al.*, 1998, 1999, 2002; Pires *et al.*, 1999), though habitat alteration by channelization and river regulation may also have acted in a way that modified streams support native fish communities with lower species diversity than the natural ones (Collares-Pereira *et al.*, 2000; Corbacho and Sánchez, 2001; Cowx and Collares-Pereira, 2002).

The length-distribution for the three endemic cyprinids variation emphasise the Odelouca and Monchique relevance, as they were the rivers where all length-classes from the three endemic cyprinids were present. Large barbels (> 80 mm) only occur at the deeper sampling sites of Monchique where riparian vegetation was more abundant. The highest biomass recorded there also confirms that Odelouca and Monchique were the preferred sites for this species. Small cyprinids (< 50 mm) never occurred at the Arade River associated to the dams situation being Enxerim and Falacho possible refuges for these sized cyprinids, particularly for *S. aradensis* and for u.n.sp. *Chondrostoma*. These small rivers with different habitats can act as complementary units in the landscape playing a critical role in promoting the persistence of native species in Mediterranean-type streams (Magalhães *et al.*, 2002b).

In harsh and variable environments such as streams in southern Iberian Peninsula, abiotic factors are likely to play an important role in determining fish assemblage structure (Matthews, 1998; Angermeier and Winston, 1999; Marchetti and Moyle, 2001; May and Brown, 2002). Although other factors not considered at the present study, such as long term flow variation, could be affecting fish community structure in these rivers, the CCA analysis revealed that environmental variables influence substantially fish assemblage structuring in the Arade basin. Variables such as water depth, substrate size, current velocity, water temperature and conductivity can be considered fundamental in the maintenance of fish assemblage structure. *S. aradensis* and u.n.sp. *Chon-*

drostoma use most of the habitats, but the former preferred deep habitats with high water temperature while the latter preferred sites with high current velocity and substrate of large dimensions, as those found in Odelouca. There was a trend for exotic species increasing in association with high conductivity and reduced oxygen. The abundance of *B. sclateri* was completely opposite to this gradient, being associated with high dissolved oxygen and some bank cover. Water depth, current velocity and substrate have previously been considered important factors in fish assemblage structuring (Gorman and Karr, 1978; Schlosser, 1982; Moyle and Vondracek, 1985; Bain *et al.*, 1988; Lobb and Orth, 1991), while high conductivities, such as those in the Arade River, were also found by Taylor *et al.* (1993) as the strongest predictor of site-specific assemblage structure. Depth could be particularly influential in Mediterranean-type rivers, since deeper pools may provide safer refugia against summer drying (Collares-Pereira *et al.*, 1998; Pires *et al.*, 1999; Godinho *et al.*, 2000; Magalhães *et al.*, 2002a, 2002b). This corresponded to the majority of the Odelouca and Monchique sites and may account for the high fish abundance and biomass recorded there. However, given the present study was performed during one single seasonal period, it is unclear whether species segregation could be associated with the temporal heterogeneity of the hydrological regime, as it was found in other studies in Iberian southern basins (Godinho *et al.*, 1997a; Pires *et al.*, 1999; Magalhães *et al.*, 2002a; Mesquita and Coelho, 2002).

Endemic fish fauna of small and isolated streams are highly vulnerable to habitat alteration (Sheldon, 1988; Moyle and Williams, 1990; Maitland, 1995; Corbacho and Sánchez, 2001; Cowx and Collares-Pereira, 2000, 2002) which confers a serious conservation problem, with most of the species being threatened, mainly because of land-use, water pollution, habitat loss, river regulation, water extraction, etc. (Almaça, 1995; Elvira, 1995; Collares-Pereira *et al.*, 1999; Ribeiro *et al.*, 2000). Although adapted to the intermittent regime, threats for endemic species in Mediterranean-type streams are likely enhanced during drought periods when abiotic conditions tend to deteriorate and concentration of fish in reduced space may raise competition and predation (Rahel and Hubert, 1991; Godinho *et al.*, 1997b; Collares-Pereira *et al.*, 1998; Pires *et al.*, 1999; Cowx, 2002; Magalhães *et al.*, 2002b). On this basis, the protection of streams and/or sites that still present characteristics to act as refugia for the endemic species, becomes a priority. Odelouca may be particularly important to fish conservation in the Arade basin in terms of species abundance, diversity and maintenance of Iberian endemic cyprinids. Indeed, this tributary could act as a refuge for both *S. aradensis* and *u.n.sp.*

Chondrostoma growing. The Monchique tributary seems to be important for the *B. sclateri* species, probably due to the existence of deep sites with high riparian cover. Enxerim appears also to be an important tributary, since it may function as an escape for the endemic species that cannot maintain stable populations in the impacted Arade River. Focusing conservation efforts in Odelouca, Monchique and Enxerim further agrees with suggestions by Angermeier and Winston (1999) in that priorities for community conservation should account for variation in fish assemblage composition across the landscape. Likewise, preventing exotic fish species invasions should also be a top priority in protecting native fish assemblages in the Arade basin.

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